

A Top-down Hierarchical Approach to the Display and Analysis of Seismic Data

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ABSTRACT

Seismic monitoring of a CTBT (Comprehensive Test Ban Treaty) will require analysts to review tens of events per hour recorded by networks of more than a hundred stations. Use of the traditional waveform display as the primary data display tool is incompatible with this requirement; traditional waveform displays are inefficient in their presentation of relevant data and place high demands on computer resources. Drawing on resident data visualization expertise and on our hands-on experience with the design and implementation of the ADSN (AFTAC Distributed Subsurface Network) system at AFTAC, we have designed a new system consisting of a hierarchical series of displays which present relevant information to the analyst in a more efficient manner. The displays are designed to be used in a top-down manner with the analyst starting with the most general display and proceeding to the most specific (the waveform display) only when it is needed. Testing to date has focussed on data from the GSETT2 (Group of Scientific Experts Technical Test #2) in 1991. Future efforts will be directed towards improved data sets from the ongoing GSETT3.

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INTRODUCTION

Full-time real-time monitoring for nuclear explosions implies high quality analysis done very quickly. Regardless of how well a monitoring system might meet one of these criteria, it cannot be used if it does not meet the other as well; thus seismic monitoring in general cannot be done on a system designed for research purposes. The entire job from signal detection to event discrimination was at one time done entirely by analysts, but a great deal of the work is now done by automatic systems. In fact, sophisticated systems such as the ADSN at AFTAC (AFTAC Distributed Subsurface Network) or the system at the IDC (International Data Center) start from the raw data and produce a complete listing of events without any analyst intervention. However, an analyst still must review all of the automatically built events and this can be very time consuming. Until a system can be developed which never misbuilds or misclassifies events, analysts will be important parts of seismic monitoring systems.

Despite the tremendous technological improvements of the last 30 years, the basic data display used by seismic analysts to review events has changed very little. Most analysts spend the majority of their time staring at some sort of display of the waveforms from the seismic stations in their network. For the research environment which emphasizes precision work on selected events, this approach still has many advantages, but as a standard method for examining the large number of events built by automatic systems, it is very inefficient. The situation will only be exacerbated as detection thresholds must be reduced for a Comprehensive Test Ban Treaty (CTBT).

The standard waveform display has several shortcomings. First, it is a poor way to display data from a large numbers of stations. For a handful of stations the display is acceptable, but for numbers of stations above 20 or so, either the waveforms must be reduced to a scale with very low resolution or the waveforms must be split into groups and viewed a screenful at a time. A second problem is that the amount of data required for the display (a waveform for each station) is large and consequently the time for such a display to be presented to the analyst is not trivial; in our own experience with the ADSN (AFTAC Distributed Subsurface Network) system at AFTAC, we have found that a significant portion of analysis time is taken up waiting for the waveform displays. Once the waveforms are displayed, an experienced analyst may need only a few seconds to decide whether an event is valid and should be refined or is bogus and should be broken; unfortunately, however, the decision generally cannot be made without going to the standard waveform display (other options are limited). Thus in theory the cost (in analyst time) of building false events should be relatively small, but in practice it can be quite large.

A third problem is that the standard display does not provide a convenient mode to display auxiliary information which may be of use to the analyst in working an event. For example, when evaluating the association (or lack thereof) of a particular station with an event, there are many parameters besides time that the analyst may use: e.g. observed distance (slowness) vs. predicted distance, observed azimuth vs. predicted azimuth, observed amplitude vs. predicted amplitude and/or amplitudes of other stations, background noise level, past recordings from known events in the same area, etc. All of this information is readily available and yet most of it is either not displayed or poorly displayed with traditional systems.

Some of these problems can be lessened by technological improvements -- multiple monitor systems can be used to display more waveforms simultaneously at acceptable resolution, and the wait for waveforms is bound to decrease as faster computers are developed -- but we believe it may be possible to achieve significant gains even with currently available resources by making a fundamental change in the way that data are presented to seismic analysts. The need for a better presentation method has never been clearer; as we move towards CTBT monitoring analysts may be faced with tens of events per hour and with networks of more than a hundred stations. To keep up, events must be dealt with very quickly, but this will be difficult given the potential number of stations to review. Routine

use of a waveform display for each event is impractical, and familiarity with the network on a station-by-station basis (a critical built-in assumption in many analysis schemes) is virtually impossible.

TOP-DOWN HIERARCHICAL DISPLAYS

A better system would present useful information to the analyst in a more efficient manner. At any given point in the analysis process, no more information should be displayed than is absolutely necessary for the analyst to complete their job. We have designed a system specifically to meet this requirement. Our system consists of a hierarchical series of displays underlain by access to all of the information available in a database populated by automatic and manual processing. The displays are meant to be accessed from the top down with the level of detail increasing as the hierarchical level decreases. The lowest level is the traditional waveform display, but it is hoped that for many events the analyst may not need it.

In designing the system, we have taken advantage of available Sandia expertise in the areas of computer visualization and seismic analysis systems (via the ADSN project). The former provides the tools for designing the interfaces while the latter provides the guidance to make them relevant. The resultant hierarchical design should not only streamline the process of analysis but it should also increase the quality of the product (i.e. an event bulletin) because the system will make the analyst better informed about network and event characteristics. The current generation of global monitoring systems (e.g. those at the IDC and at AFTAC) populate huge numbers of fields in database accounts with numerical measurements quantifying various parameters relevant to seismic analysis (phases, events, instrumentation at each station, noise levels, etc.) and yet much of this information is not presented to the analysts. This is doubly unfortunate because not only might the information be helpful, but typically access to it is much quicker than to the waveforms.

Our system presents the database information first, and then the waveforms if necessary; the underlying principal in the design of the new system is to present increasing levels of detailed only as they are needed. This is in direct contrast to traditional systems where the analyst frequently starts with the waveforms. Our current version of the system has three levels: a Global Event Summary Display, an Event Quality Display, and a traditional Waveform Display.

1. Global Event Summary

The Global Event Summary Display (GESD) provides a high level summary of the seismic activity and other relevant information (e.g. seismicity, known nuclear test locations, known mine locations, etc.) for a specified time period as determined by the analyst. The map portion of the display shows all of the events in the specified time period with certain (selectable) characteristics highlighted by visual cues (color, size, shape, etc.). In many cases the geographic location alone will decide the next course of action, but for other events the additional information displayed (e.g. depth, magnitude, number of

reporting stations, station locations, discriminations results, error ellipse, depth error) may considerably streamline subsequent analysis.

Main Display -- Global Event Summary

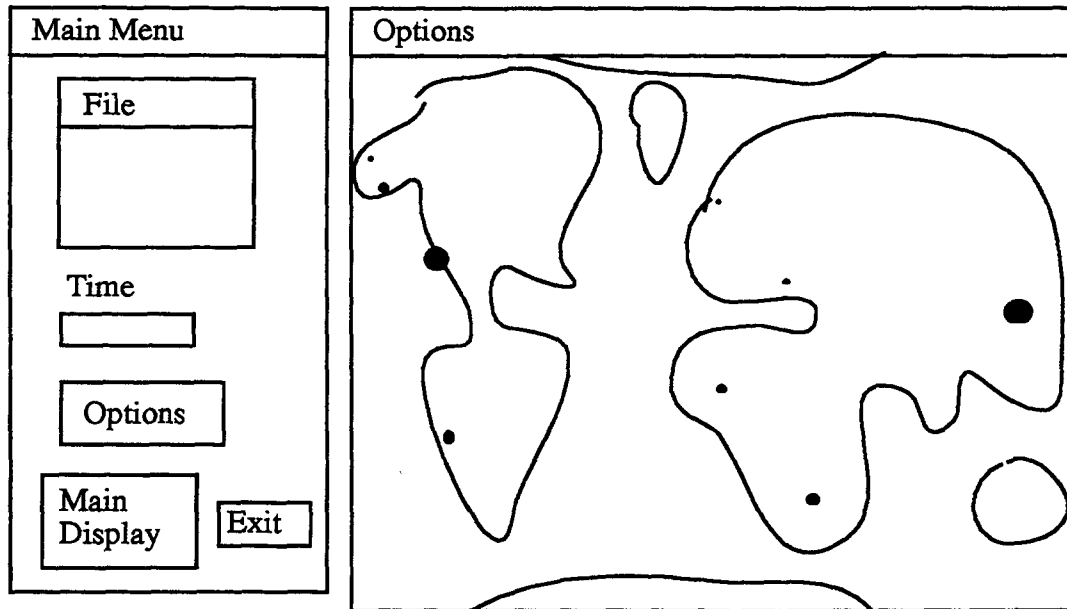


FIGURE 1. Cartoon of basic design for the GESD. The left side of the display contains various widgets (radio buttons, pull-down menus, text boxes) for specifying parameters to be displayed. The right side is a map with various superimposed objects representing relevant items such as events, stations, locations and types of known sources.

The GESD is linked to the next level, the Event Quality Display (EQD) by means of the events displayed in the GSED map: selecting an event will automatically bring up the EQD for that event.

2. Event Quality Display

The EQD provides a detailed view of the information relevant to a specific event. The basic information displayed includes the location of the event and the stations in the network, but a great amount of additional information can be projected onto these objects using visual cues. Potential parameters include:

- Event: depth, error information, number of defining stations, number of associated phases, magnitudes, discrimination results)
- Station: type of station (array, three component, etc.), noise level, signal-to-noise ratio, station magnitude, predicted amplitude, observed azimuth and slowness, theoretical azimuth and slowness

As much of the information as can be reasonably comprehended will be mapped via visual cues, but a complete summary of the relevant information is available in a text window as well.

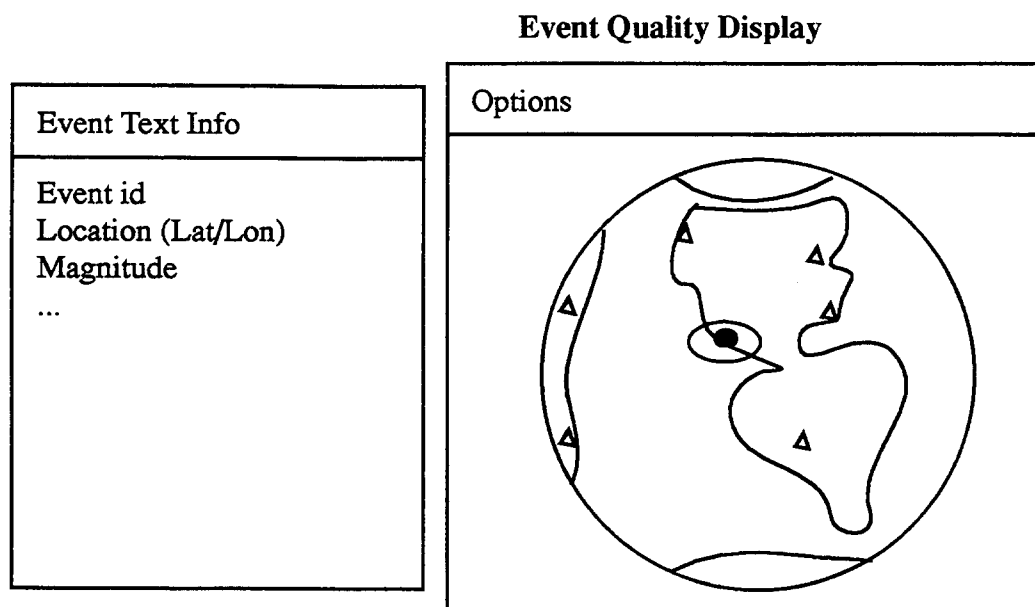


FIGURE 2. Cartoon of basic design for the EQD. The left side provides a (text) listing of information relevant to the event. The right side is a map display centered on the event with various other objects plotted which may be of use to the analyst. Parameters displayed and the visual cues (color, size, shape, etc.) used to highlight them can be set via pull-down menus.

The final display level, the traditional Waveform Display can be triggered either by clicking on stations (selected waveforms displayed) or on the event (all waveforms displayed).

3. Waveform Display

The waveform display provides the traditional times series and related displays (e.g. FK diagrams) used to analyze seismic data in detail. Rather than design a new waveform display, we plan to use one of the numerous available existing, mature packages (e.g. ARS, geotool, SAC).

PLATFORM AND DATA SET

The GESD and the EQD are being developed using the AVS/Express data visualization package running on an SGI Onyx. To date we have tested the displays using data from the GSETT2 (Group of Scientific Experts Technical Test #2) experiment in 1991 which are stored in a CSS3.0 format Oracle database.

FUTURE PLANS

Though useful for testing a prototype, the GSETT2 data set is limited: it contains only the final database account (after both the automatic system and the analyst have worked the data), the number of high quality stations is limited, and many of the database tables are not fully populated. In the near future we plan to begin to test our displays using information from the IDC database for the ongoing GSETT3. This data set is much more complete than that for GSETT2 and it contains several separate accounts which can be used to compare the value added by the automated system with that added by the analyst.

In particular we are interested in trying to provide visual cues which can help identify the events that are not common to both the automatic and analyst generated accounts. If

the proper combination of cues could make it possible to quickly identify bogus events (i.e. those rejected by the analysts in reviewing the output of the automated system) from either the GESD or the EQD, a significant amount of analysis time could be saved. Conversely, the proper use of visual cues for the events hand-built by the analysts might provide valuable guidance into the common features of those events which could then be fed back into the automatic system so that it could build them.

CONCLUSIONS

Although traditional waveform displays are still widely used, their inefficient presentation of relevant data and the high demands they place on computer resources make their replacement a priority for CTBT seismic monitoring. Drawing on in-house data visualization expertise and on our hands-on experience with the design and implementation of the ADSN system at AFTAC, we have designed a new system consisting of a hierarchical series of displays which present relevant information to the analyst in a much more efficient manner. The analyst starts with the most general display and proceeds to increasingly detailed displays only as they are needed. The traditional waveform display is the final level of detail and will still be used but only for events that require detailed analysis. So far all of our testing has been done on data from the GSETT2 in 1991, but in the near future we plan to start using the much more complete data set from the ongoing GSETT3.